

Description

METHOD FOR PATTERNING HFO₂-CONTAINING DIELECTRIC

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a method for patterning an HfO₂-containing dielectric, and more particularly, to a method for patterning an HfO₂-containing gate dielectric without damaging STI positioned on the same wafer.

[0003] 2. Description of the Prior Art

[0004] For realizing the low power MOS transistor at the 65nm node and beyond, it is necessary to reduce the gate leakage current for thinner gate dielectrics. The introduction of high-k gate material would be advantageous for extending current MOS technology. After several years of work, many research groups are now focusing on hafnium (Hf) based material and are evaluating the natural of these materials extensively. Among the considerable Hf-based

materials, HfO₂ is often evaluated to be combined into a metal gate structure.

- [0005] However, HfO₂-containing dielectric (including HfO₂, Hf-SiO, HfSiON, HfAlO, and so on) is known for more difficult to be pattern etched comparing to SiO₂ based dielectric. The conventional method of etching the HfO₂-containing dielectric involves using a strong acid, such as 49% HF solution. When using the 49% HF solution to etch the HfO₂-containing dielectric, a SiO₂ layer, such as a shallow trench isolation (STI) layer, will be also removed. Furthermore, the etching rate of the SiO₂ layer is much higher than that of the HfO₂-containing dielectric, and the SiO₂ layer will be seriously damaged while patterning the HfO₂-containing dielectric.
- [0006] Another conventional method of etching the HfO₂-containing dielectric is using a high insert gas plasma with more than 60% Ar. The insert gas plasma has no selectivity while etching, and may also result in the SiO₂ layer being damaged during over-etch.
- [0007] Please refer to Figs. 1 and 2, which show a conventional etching process of the HfO₂-containing dielectric. An STI layer 18 is formed on a wafer 10, and an HfO₂-containing gate dielectric 12 covers the wafer 10 and the STI layer

18. A gate electrode 16 is formed on the HfO₂-containing gate dielectric 12, and two spacers 14 are formed beside the gate electrode 16. As shown in Fig. 2, the conventional etching process such as using the strong acid or the insert gas plasma is performed to remove portions of the HfO₂-containing gate dielectric 12. The etching selectively between the HfO₂-containing gate dielectric 12 and the STI layer 18 is too low to bring serious damages atop the STI layer 18. As a result, the isolation effect of the STI layer 18 is reduced.

SUMMARY OF INVENTION

- [0008] It is therefore a primary objective of the claimed invention to provide a method for patterning the HfO₂-containing gate dielectric without damaging the SiO₂ layer to solve the above-mentioned problem.
- [0009] According to the claimed invention, a method for patterning an HfO₂-containing gate dielectric comprises providing a wafer having a trench, a STI layer formed in the trench, the HfO₂-containing gate dielectric covering the wafer and the STI layer, a gate electrode formed on the HfO₂-containing gate dielectric, and at least a spacer formed beside the gate electrode. Following that, the wafer is preheated and a bromine-rich gas plasma is pro-

vided to remove portions of the HfO₂-containing gate dielectric.

- [0010] According to the claimed invention, a method for patterning an HfO₂-containing gate dielectric comprises providing a wafer having a trench, a STI layer formed in the trench, the HfO₂-containing gate dielectric covering the wafer and the STI layer, a gate electrode formed on the HfO₂-containing gate dielectric, and at least a spacer formed beside the gate electrode. Following that, a nitrogen ion bombardment is used to convert the exposed HfO₂-containing gate dielectric to a Hf₃N₄ layer. A phosphoric acid is used to remove the Hf₃N₄ layer.
- [0011] It is an advantage of the claimed invention that the bromine-rich gas plasma has a high selectivity between the HfO₂-containingdielectric and the SiO₂ layer, so that the HfO₂-containingdielectric can be etched without damaging the SiO₂ layer.
- [0012] It is another advantage of the claimed invention that the nitrogen ion bombardment can convert the HfO₂-containingdielectric to the Hf₃N₄ layer and the phosphoric acid has a high selectivity between the Hf₃N₄ and SiO₂ layers, so that the HfO₂-containingdielectric can be etched without damaging the SiO₂ layers.

[0013] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0014] Fig. 1 is a schematic diagram of a wafer before performing a gate dielectric patterning process thereon according to the prior art;

[0015] Fig. 2 is a schematic diagram of a wafer after performing a gate dielectric patterning process thereon according to the prior art;

[0016] Fig. 3 is a schematic diagram of a wafer after performing a gate dielectric patterning process thereon according to the present invention; and

[0017] Fig. 4 is a schematic diagram of a wafer after performing a gate dielectric patterning process thereon according to a second embodiment of the present invention.

DETAILED DESCRIPTION

[0018] Please refer to Fig. 3, which shows a result of performing a patterning process according to a first embodiment of the present invention. In the first embodiment of the

present invention, a bromine-rich gas plasma is utilized to accomplish the requirement of etching the HfO₂-containing dielectric with a high selectivity. In this embodiment, a MOS transistor fabrication is used to explain the present invention. Before the etching process, the half-manufactured wafer is similar to that of the prior art as shown in Fig. 1. For example, the STI layer 18 is formed on the wafer 10, and the HfO₂-containing gate dielectric 12 covers the wafer 10 and the STI layer 18. The gate electrode 16 is formed on the HfO₂-containing gate dielectric 12, and two spacers 14 are formed beside the gate electrode 16. The STI layer 18 and the spacer 14 may be formed of SiO₂, and the gate electrode 16 may be formed of TaN or TiN.

- [0019] Then, the wafer 10 is placed into a reactor and is pre-heated to 200°C or over 200°C. The reactor can be any type of plasma reactors, such as the parallel plate, the reactive ion etcher (RIE), the inductively coupled plasma (ICP), or the electron cyclotron resonance etcher (ECR), and the preheating procedure can utilize a lamp tray or a non-reactive gas plasma to preheat the wafer 10.
- [0020] After the wafer 10 is preheated to 200°C or over 200°C, the bromine-rich gas plasma is supplied into the reactor

to remove portions of the HfO₂-containing gate dielectric 12. The bromine-rich gas plasma can be a Br₂ plasma, a HBr plasma, or a mixture of a Br₂ plasma and a HBr plasma, and concentration of the bromine-rich gas plasma is higher than 30%. On the wafer surface, the bromine-rich gas plasma will react with the HfO₂-containing gate dielectric 12 and produce a volatile product HfBr₄. At the elevated temperature ($\geq 200^{\circ}\text{C}$), HfBr₄ is volatile and can be taken out by the pumping system. After removing portions of the HfO₂-containing gate dielectric 12, the STI layer 18 is exposed. Since the bromine-rich gas plasma etches the SiO₂ material of the STI layer 18 much slower than the HfO₂-containing gate dielectric 12, the STI layer 18 will be almost undamaged. In addition, a sacrifice layer (not shown) can be further formed on the gate electrode 16 before performing the patterning process to protect the gate electrode 16. The sacrifice layer may be formed of SiO₂.

- [0021] Furthermore, in other embodiments of the present invention, additive gases, such as Ar, N₂, He, O₂, CHF₃, etc., can be introduced into the reactor to assist uniform etching of the HfO₂-containing gate dielectric 12. It is also worthy of notice that the present invention is not limited

to pattern the HfO₂-containing gate dielectric. The present invention is also applicable in any etching process relating to pattern HfO₂-containing dielectric. For example, a wafer having an HfO₂-containing dielectric is provided, and the wafer is preheated to a predetermined temperature. Following that, a bromine-rich gas plasma is provided to remove portions of the HfO₂-containing dielectric, thus providing a high etching selectivity in etching HfO₂.

- [0022] Another embodiment of the present invention is utilizing a nitrogen ion bombardment to convert the exposed HfO₂-containing dielectric to an Hf₃N₄ (Hafnium Nitride) layer and then utilizing a phosphoric acid to remove the Hf₃N₄ layer. Please refer to Fig. 4, which shows the patterning process of the second embodiment. A nitrogen ion bombardment is performed on the half-manufactured wafer 10, and the exposed HfO₂-containing gate dielectric 12 is converted to an Hf₃N₄ layer 20. While performing the nitrogen ion bombardment, a nitrogen gas or a nitrogen-contained gas can be used to produce the nitrogen ions. The regions covered by the gate electrode 16 and the spacers 14 are protected and retain the HfO₂-containing material. Selectively, a sacrifice layer (not

shown) can be also formed on the gate electrode 16 before performing the nitrogen ion bombardment to protect the gate electrode 16.

- [0023] After the nitrogen ion bombardment, the Hf₃N₄ layers 20 are formed beside the portion of HfO₂-containing gate dielectrics 12 under the gate electrode 16 and the spacers 14. The Hf₃N₄ layers 20 are easily etched by the phosphoric acid. In this embodiment, a H₃PO₄ solution is utilized to remove the Hf₃N₄ layers 20, but the H₃PO₄ solution etches neither the SiO₂ layer nor the Si layer. The STI layers 18 will be almost undamaged after the Hf₃N₄ layers 20 is removed. In addition, for speeding the removing process, the H₃PO₄ solution can be maintained at the temperature 50°C–300°C. It is also worthy of notice that the present invention is not limited to pattern the HfO₂-containing gate dielectric. The present invention is also applicable in any etching process relating to pattern HfO₂-containing dielectric. For example, a wafer having an HfO₂-containing dielectric is provided, and a nitrogen ion bombardment is used to convert portions of the HfO₂-containing dielectric to an Hf₃N₄ layer. Following that, a phosphoric acid is used to remove the Hf₃N₄ layer, thus providing a high etching selectivity in etching HfO₂.

- [0024] In contrast to the prior art, the present invention has a high etching selectivity between the HfO₂-containing material and the SiO₂ material, so that the STI layer can be retained complete after the gate dielectric is removed.
- [0025] Those skilled in the art will readily observe that numerous modifications and alterations of the device may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.